influence of the group delay characteristic of a transmission line and the like (the characteristic that a propagation delay varies depending on a frequency). Therefore, the transmission line must be designed with particular attention. However, as a signal band becomes wider, the group delay variations in the band become more difficult to sufficiently suppress.

A1 conc'l.

Please replace the paragraphs beginning at page 4, line 23 through page 10, line 5, with the following rewritten paragraphs:

Therefore, an object of the present invention is to provide an optical transmission system capable of narrowing the bandwidth of an FM modulated signal while increasing the frequency deviation thereof to realize high-quality signal transmission. The present invention has the following features to attain the object above.

A2

A first aspect of the present invention is directed to a transmission system for optically transmitting a frequency-division-multiplexed signal, which is obtained by frequency-division multiplexing a plurality of signals, from a transmitting end to a receiving end. The transmission system comprises at the transmitting end, a multiplexer for frequency-division multiplexing the plurality of signals to produce the frequency-division-multiplexed signal, an FM modulator for converting the frequency-division-multiplexed signal into a frequency-modulated signal through frequency modulation using the frequency-division-multiplexed signal as an original signal to output the frequency-modulated signal as an FM modulated signal, and an optical transmitter for converting the FM modulated signal into an optical-intensity-modulated signal whose optical carrier component is suppressed in the optical frequency spectrum through optical modulation using the FM modulated signal as an original signal to send the optical-intensity-modulated signal to the receiving end. The transmission system also comprises at the receiving end, an optical receiver for receiving the optical-intensity-modulated signal from the optical transmitter, and converting the optical-intensity-modulated signal into an electrical signal corresponding to the FM modulated signal through photodetection based on a square-law detection characteristic to output the electrical signal as a received FM modulated signal, and an FM demodulator for demodulating the received FM modulated signal to reproduce the frequency-division-multiplexed signal.

24

a

As described above, in the first aspect, the FM modulated signal is obtained through frequency modulation using a frequency-division-multiplexed signal as an original signal. The FM modulated signal is converted into an optical-intensity-modulated signal at the transmitting end. The optical-intensity-modulated signal has an optical frequency spectrum in which upper and lower sidebands distribute geometrically similarly to the frequency spectrum of the original signal for the optical modulation and in which an optical carrier component is suppressed. Then, the optical-intensity-modulated signal is photodetected based on a square-law detection characteristic at the receiving end. At the receiving end, the optical transmission system thus obtains an FM modulated signal, having a frequency deviation twice as large as the one of the original FM modulated signal produced at the transmitting end, as a received FM modulated signal. In this manner, the optical transmission system can narrow (reduce in half) the bandwidth of the FM modulated signal at the transmitting end while securing the frequency deviation thereof large enough to acquire a sufficient FM gain in FM demodulation. As a result, it is possible to prevent the waveform of the transmitted signal from being deteriorated due to the group delay characteristic of the electrical transmission line and the chromatic-dispersion of the optical transmission line, and to realize signal transmission of good quality.

According to a second aspect, in the first aspect, the optical transmitter includes a light source for outputting an unmodulated light, and an optical modulator for modulating the unmodulated light with the FM modulated signal to produce the optical-intensity-modulated signal. The optical modulator has the Mach-Zehnder interferometer structure with a predetermined input-voltage vs. output-optical-power characteristic, and is biased in the input-voltage vs. output-optical-power characteristic such that the output optical power is at the minimum.

As stated above, in the second aspect, the optical modulator used herein is an external optical modulator having the Mach-Zehnder interferometer structure. A modulating signal (an FM modulated signal) is applied to the optical modulator with respect to the "valley" where the output optical power is at the minimum in the input-voltage vs. output-optical-power characteristic (which is periodic like a sine wave) of the optical modulator. The optical modulator thus produces an optical-intensity-modulated signal whose optical carrier component is

27

suppressed. The suppression of the optical carrier component prevents the waveform from being deteriorated by the chromatic-dispersion of the optical transmission line. In addition, the optical-intensity-modulated signal has an optical frequency spectrum in which upper and lower sidebands distribute geometrically similarly to the frequency spectrum of the original signal for the optical modulation. Therefore, after the optical-intensity-modulated signal is square-law detected at the receiving end, the frequency deviation of the FM modulated signal is doubled, thereby making it possible to realize high-quality signal transmission.

According to a third aspect, in the second aspect, the transmission system further comprises a frequency-divider provided between the FM modulator and the optical transmitter for converting the FM modulated signal outputted from the FM modulator into a frequency-divided FM modulated signal whose frequency is $1/2^n$ the frequency of the FM modulated signal, the n being an integer of not less than 1, wherein the optical modulator modulates the unmodulated light with the frequency-divided FM modulated signal to produce the optical-intensity-modulated signal.

a Xt. tru

As described above, in the third aspect, the optical transmission system previously produces in the FM modulator an FM modulated signal having a frequency deviation larger enough to acquire a desired FM gain. The optical transmission system then converts the FM modulated signal into a frequency-divided FM modulated signal, and next converts the frequency-divided FM modulated signal into an optical-intensity-modulated signal for transmission. This reduces the phase noise in the FM modulated signal to be optically transmitted and FM demodulated. As a result, high-quality signal transmission can be realized.

According to a fourth aspect, in the first aspect, the optical transmitter includes a light source for outputting an unmodulated light, an optical branching circuit for branching the unmodulated light fed from the light source into first and second unmodulated lights, an optical modulator for modulating the first unmodulated light with the FM modulated signal to produce the optical-intensity-modulated signal, the optical modulator having the Mach-Zehnder interferometer structure with a predetermined input-voltage vs. output-optical-power characteristic, and being biased in the input-voltage vs. output-optical-power characteristic such that the output optical power is at the maximum, and an optical combining circuit for combining

28

a

the optical-intensity-modulated signal produced by the optical modulator and the second unmodulated light to cancel the optical carrier component of the optical-intensity-modulated signal with the second unmodulated light and output the optical-intensity-modulated signal whose optical carrier component is suppressed.

Please replace the paragraph beginning at page 11, line 14, with the following rewritten paragraph:

As described above, in the fifth aspect, the optical-intensity-modulated signal produced by the optical modulator is combined with the second unmodulated light set in an opposite phase to the optical carrier component of the optical-intensity-modulated signal. The optical carrier component of the optical-intensity-modulated signal is thus canceled by the second unmodulated light. As a result, it is possible to produce an optical-intensity-modulated signal whose optical carrier component is suppressed.

Please replace the paragraphs beginning at page 11, line 23 through page 12, line 7, with the following rewritten paragraph:

According to a sixth aspect, in the fourth aspect, the transmission system further comprises a frequency-divider provided between the FM modulator and the optical transmitter for converting the FM modulated signal outputted from the FM modulator into a frequency-divided FM modulated signal whose frequency is $1/2^n$ the frequency of the FM modulated signal, the n being an integer of not less than 1, wherein the optical modulator modulates the first unmodulated light with the frequency-divided FM modulated signal to produce the optical-intensity-modulated signal.

Please replace the paragraphs beginning at page 12, line 17, through page 13, line 2, with the following rewritten paragraph:

According to a seventh aspect, in the first aspect, the transmission system further comprises a frequency-divider provided between the FM modulator and the optical transmitter for converting the FM modulated signal outputted from the FM modulator into a frequency-divided

29

a

FM modulated signal whose frequency is $1/2^n$ the frequency of the FM modulated signal, the n being an integer of not less than 1, wherein the optical transmitter includes an optical modulator for producing the optical-intensity-modulated signal through the optical modulation using the frequency-divided FM modulated signal as an original signal.

Please replace the paragraphs beginning at page 13, line 12, through page 14, line 5 with the following rewritten paragraph:

An eighth aspect of the present invention is directed to an transmitter for use in a transmission system for optically transmitting a frequency-division-multiplexed signal, which is obtained by frequency-division-multiplexing a plurality of signals, from a transmitting end to a receiving end. The transmitter comprises a multiplexer for frequency-division multiplexing the plurality of signals to produce the frequency-division-multiplexed signal, an FM modulator for converting the frequency-division-multiplexed signal into a frequency-modulated signal through frequency modulation using the frequency-division-multiplexed signal as an original signal to output the frequency-modulated signal as an FM modulated signal, and an optical transmitter for converting the FM modulated signal into an optical-intensity-modulated signal whose optical carrier component is suppressed in the optical frequency spectrum through optical modulation using the FM modulated signal as an original signal to send the optical-intensity-modulated signal to the receiving end.

Please replace the paragraphs beginning at page 14, line 6, through page 14, line 16 with the following rewritten paragraph:

According to a ninth aspect, in the eighth aspect, the optical transmitter includes a light source for outputting an unmodulated light, and an optical modulator for modulating the unmodulated light with the FM modulated signal to produce the optical-intensity-modulated signal, the optical modulator having the Mach-Zehnder interferometer structure with a predetermined input-voltage vs. output-optical-power characteristic, and being biased in the input-voltage vs. output-optical-power characteristic such that the output optical power is at the minimum.

30

a

Please replace the paragraphs beginning at page 14, line 17, through page 15, line 1 with the following rewritten paragraph:

According to a tenth aspect, in the ninth aspect, the transmitter further comprises a frequency-divider provided between the FM modulator and the optical transmitter for converting the FM modulated signal outputted from the FM modulator into a frequency-divided FM modulated signal whose frequency is $1/2^n$ the frequency of the FM modulated signal, the n being an integer of not less than 1, wherein the optical modulator modulates the unmodulated light with the frequency-divided FM modulated signal to produce the optical-intensity-modulated signal.

Please replace the paragraphs beginning at page 15, line 2, through page 16, line 6, with the following rewritten paragraph:

According to an eleventh aspect, in the eighth aspect, the optical transmitter includes a light source for outputting an unmodulated light, an optical branching circuit for branching the unmodulated light fed from the light source into first and second unmodulated lights, an optical modulator for modulating the first unmodulated light with the FM modulated signal to produce the optical intensity-modulated signal, the optical modulator having the Mach-Zehnder interferometer structure with a predetermined input-voltage vs. output-optical-power characteristic, and being biased in the input-voltage vs. output-optical-power characteristic such that the output optical power is at the maximum, and an optical combining circuit for combining the optical-intensity-modulated signal produced by the optical modulator and the second unmodulated light to cancel the optical carrier component of the optical-intensity-modulated signal with the second unmodulated light, and output the optical-intensity-modulated signal whose optical carrier component is suppressed.

Please replace the paragraphs beginning at page 16, line 7, through page 16, line 16, with the following rewritten paragraph:

According to a thirteenth aspect, in the eleventh aspect, the transmitter further comprises a frequency-divider provided between the FM modulator and the optical transmitter for converting the FM modulated signal outputted from the FM modulator into a frequency-divided FM

31

a

modulated signal whose frequency is $1/2^n$ the frequency of the FM modulated signal, the n being an integer of not less than 1, wherein the optical modulator modulates the first unmodulated light with the frequency-divided FM modulated signal to produce the optical-intensity-modulated signal.

Please replace the paragraphs beginning at page 16, line 17, through page 17, line 2 with the following rewritten paragraph:

A4 cont.

According to a fourteenth aspect, in the eighth aspect, the transmitter further comprises a frequency-divider provided between the FM modulator and the optical transmitter for converting the FM modulated signal outputted from the FM modulator into a frequency-divided FM modulated signal whose frequency is $1/2^n$ the frequency of the FM modulated signal, the n being an integer of not less than 1, wherein the optical transmitter includes an optical modulator for producing the optical-intensity-modulated signal through optical modulation using the frequency-divided FM modulated signal as an original signal.

Please replace the paragraph beginning at page 21, line 10 through page 23, line 1, with the following rewritten paragraph:

A5

Next, referring to FIGS. 2A to 2C, the operation of the present embodiment shown in FIG. 1 is described. FIGS. 2A to 2C schematically illustrate the frequency spectrums of respective signals in the optical transmission system in FIG. 1. FIG. 2A shows the frequency spectrum of an output signal of the FM modulator 101. FIG. 2B shows the optical frequency spectrum of an output signal (optical signal) of the optical modulator 104. FIG. 2C shows the frequency spectrum of an output signal of the optical receiver 106. In the optical transmission system shown in FIG. 1, the multiplexer 100 frequency-division multiplexes a plurality of signals, and outputs the resultant signal to the FM modulator 101. The FM modulator 101 converts the frequency-division-multiplexed signal into an FM modulated signal through frequency modulation. The FM modulated signal has a frequency spectrum as shown in FIG. 2A in which a carrier frequency is fc and a frequency deviation is ΔF. After that, the FM modulator outputs the FM modulated signal to the electrical transmission line 102. The light source 103 outputs an

32

a